

**NASA TECHNICAL  
MEMORANDUM**

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**NATURAL ENVIRONMENT DESIGN REQUIREMENTS  
FOR THE SPACE TUG**

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16. ABSTRACT  <p>Given in this report are the natural environment design requirements for the Space Tug. Since the Space Tug is carried as "cargo" to orbital altitudes in the Space Shuttle bay, orbital environmental impacts and short-period atmospheric density variations are the main concerns of this report.</p>					
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## 1.0 PURPOSE AND SCOPE

The definition of natural environment design requirements for Space Tug missions.

## 2.0 NATURAL ENVIRONMENT - GENERAL

The natural environment criteria given in this report are consistent with those specified for the Space Shuttle system and will be used for design of the Space Tug with respect to radiation atmospheric characteristics at orbital altitudes, and other pertinent natural environment requirements. Design value requirements of natural environment parameters not specifically defined in this report will be obtained from NASA TM X-64587, "Terrestrial Environment (Climatic) Criteria Guidelines for Use in Space Vehicle Development, 1971 Revision," dated May 10, 1971 [1], and NASA TM X-64627, "Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development, 1971 Revision," dated November 15 1972 [2], and subsequent addenda to those documents. The Space Tug will be subject to environmental factors peculiar to the Space Shuttle during assembly, checkout, launch, and attainment of orbital positioning prior to removal of the Space Tug from the Shuttle bay; therefore, appropriate Shuttle documents should be consulted when the Space Tug is "cargo" in the Space Shuttle.

Natural environmental data not given in the above and required in design or mission analyses for the Space Tug will be requested from or approved by the MSFC Aerospace Environment Division through the cognizant NASA Contract Representative prior to use.

## 3.0 NEUTRAL ATMOSPHERE - ORBITAL ALTITUDES

3.1 The Jacchia 1970 Model Atmosphere will be used. See Appendix B, NASA TM X-64627 for details.

3.2 The design steady-state values of the orbital neutral atmospheric gas properties shall be calculated using a value of 230 for the mean 10.7 cm solar flux and a geomagnetic index ( $a_p$ ) of 20.3 with a local time of day of 0900 hr as inputs to the Jacchia 1970 Model Atmosphere.

3.3 The design short-time extreme values of the atmospheric gas properties shall be calculated using a value of 230 for the mean 10.7 cm solar flux and a geomagnetic index ( $a_p$ ) value of 400, and a local time

of day of 1400 hr as input to the Jacchia 1970 Model Atmosphere. These orbital neutral atmospheric gas property values represent an estimate of the conditions that may occur for a short period of time (12 to 36 hrs) during an extremely large magnetic storm.

3.4 Exosphere (37,000 km Geosynchronous Orbital Altitude) - The data given in Section 2.2.2 of NASA TM X-64627 shall be used.

3.5 Short-Period Atmospheric Density Variations for Use in Space Tug Aerobraking Analyses

One method for returning the Space Tug from a synchronous orbital altitude to the Space Station or Shuttle orbital altitude is dependent not only on the atmospheric mass density at some predetermined altitude between approximately 80 and 120 km, but also on a guidance and control system which could correct for variations in the density encountered at the perigee altitude.

The aerobraking maneuver could be accomplished in from one to approximately thirty passes through the 80-120 km altitude region. The time between successive perigee passes, and hence the locations of perigee, is variable and dependent upon the mass density encountered at the previous perigee altitude.

The density histories presented in Figure 1 are realistic conditions that might be encountered during the aerobraking maneuvers where the atmosphere may vary significantly between successive perigee locations. These density histories apply only to the equatorial regions of the earth between  $\pm 28^\circ$  latitude and should be used in evaluating the operational capability of the proposed Space Tug aerobraking capability relative to the available guidance and control systems. The abscissas of the graphs are scaled so that time,  $t = 0$ , refers to the time of the initial perigee pass and the density values for all additional passes should be determined from the curve using the time elapsed since the initial perigee pass.

These data have been developed using available data sources and models for the specific applications noted above. They should not be used for generalized interpretation as a model of the upper atmospheric density structure for other analyses without prior consultation with the originator.

#### 4.0 CHARGED PARTICLES

The electron density values and data in Section 2.3 of NASA TM X-64627 shall be used.

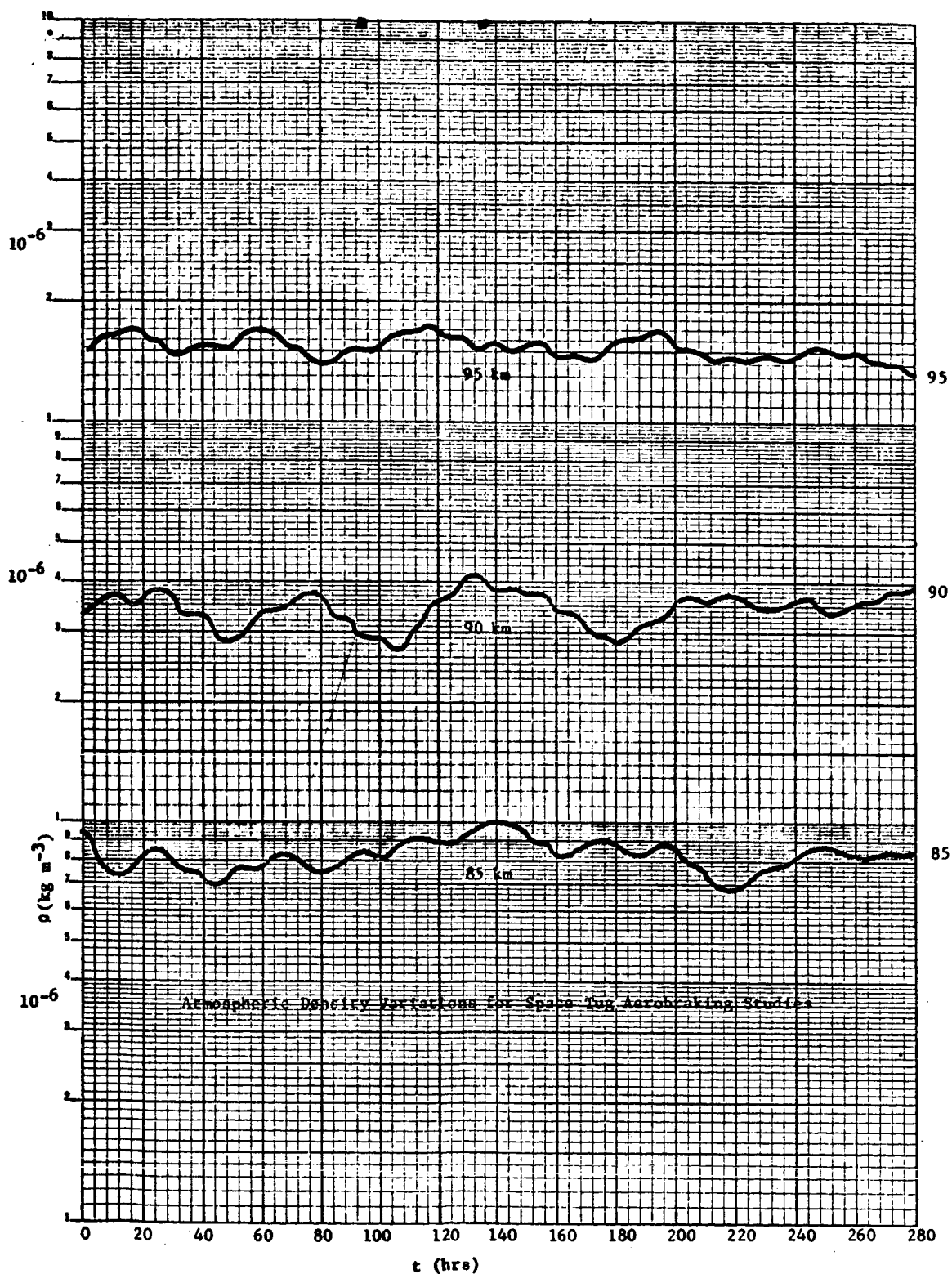


Figure 1. Atmospheric Density Variations for Space Tug Aerobraking Studies

## 5.0 RADIATION

In addition to the following, use Section 2.4 of NASA TM X-64627. The Space Tug shall be designed to provide necessary protection to insure the safe dosage limits of the equipment are not exceeded.

5.1 Galactic Cosmic Radiation - Galactic cosmic radiation consists of low intensity, extremely high energy charged particles. These particles, about 85 percent protons, 13 percent alphas, and the remainder heavier nuclei, bombard the solar system from all directions. They have energies from  $10^8$  to  $10^{19}$  electron volts (ev) per particle and are encountered essentially everywhere in space. The intensity of this environment in "free-space," e.g., outside the influence of the earth's magnetic field, is relatively constant (.2 to .4 particles per square centimeter per steradian per second) except during periods of enhanced solar activity when the fluxes of cosmic rays have been observed to decrease due to an increase in the strength of the interplanetary magnetic field which acts as a shield to incoming particles. Near the earth, cosmic rays are similarly influenced by the earth's magnetic field resulting in a spatial variation in their intensity. The extreme of the galactic cosmic ray environment is at sunspot minimum. The environment is constant and may be scaled down to 24 hours. See Section 2.4.1 of NASA TM X-64627 for additional data on this subject.

Estimates of the daily cosmic ray dose for the various orbits are shown in Table 1. These should be considered in the Space Tug studies.

Table 1. Galactic Cosmic Ray Dose Rates (REM/Day)

	255 n.m. 55° Incl.	200 n.m. Polar	Geo- synchronous
Solar Maximum	0.005	0.008	0.024
Solar Minimum	0.008	0.013	0.036

5.2 Trapped Radiation - The trapped radiation environment will be taken from most recent data of NASA SP-3024 (currently in six volumes) or from the TRECO computer code available from the National Space Science Data Center, NASA/Goddard Space Flight Center, and merged with trajectory information to find particle fluxes and spectra. The fluxes

and spectra will be converted to dose by data and/or computer codes provided by MSFC/S&E-SSL-NR (see Section 2.4.2 of NASA TM X-64627).

5.2.1 Near-Earth Environment - The radiation belts trapped near the earth are approximately azimuthally symmetric, with the exception of the South Atlantic Anomaly where the radiation belts reach their lowest altitude. The naturally occurring trapped radiation environment in the anomaly region remains fairly constant with time although it does fluctuate with solar activity. Electrons will be encountered at low altitudes in the anomaly region as well as in the auroral zones.

5.2.2 Synchronous Orbit Altitude Environment - The trapped proton environment at synchronous orbit altitude is of no direct biological significance, but may cause deterioration of material surfaces over long exposure times. The proton flux at this altitude is composed of only low energy protons (less than 4 Mev) and is on the order of  $10^5$  protons/cm<sup>2</sup>-sec. The trapped electron environment at synchronous altitude is characterized by variations in particle intensity of several orders of magnitude over periods as short as a few hours. However, for extended synchronous altitude missions, a local time averaged environment can be used. See Section 2.4.2.2 of NASA TM X-64627 for additional data.

5.3 Solar Particle Events - Solar particle events are the emission of charged particles from disturbed regions on the sun during solar flares. They are composed of energetic protons and alpha particles that occur sporadically and last for several days. The free-space particle event model to be used for Space Tug orbital studies is given in Section 2.4.3.1 of NASA TM X-64627.

5.4 Radiation Dose Limits - Table 2 (p. 6) lists the allowable radiation limits for the flight crews to be used for all applicable program considerations. These values are based on information contained in "Radiation Protection Guides and Constraints for Space - Mission and Vehicle - Design Studies Involving Nuclear Systems," a report of the Radiobiological Advisory Panel of the Committee on Space Medicine, Space Science Board, National Academy of Sciences. The Radiobiological Advisory Panel's concept of a primary reference risk is adopted and a unit reference risk is considered acceptable for the subject manned space flight programs.

## 6.0 METEOROID

The Space Tug shall be designed for at least a 0.95 probability of no puncture during the maximum total time in orbit using the meteoroid model defined in Section 2.5.1 of NASA TM X-64627.



6.1 Meteoroid Impact - Space Tug meteoroid impact requirements shall be as specified below:

a. Pressure Loss - The Space Tug Manned Volume, when utilized, shall be protected from meteoroid impact damage which would result in pressure loss when subjected to the meteoroid flux model as defined in NASA TM X-64627.

b. Functional Capability - The Space Tug shall provide protection against loss of functional capability of selected critical items when subjected to the meteoroid flux model as defined in NASA TM X-64627. The probability of no penetration shall be assessed on each item dependent upon function criticality.

Table 2. Radiation Exposure Limits and Exposure Rate Constraints for Unit Reference Risk

Constraints in REM	(REM) Bone Marrow (5 cm)	Skin (0.1 mm)	Eye (3 mm)	Testes <sup>2</sup> (3 cm)
1 yr avg. daily rate	0.2	0.6	0.3	0.1
30-day maximum	25	75	37	13
quarterly maximum <sup>1</sup>	35	105	52	18
yearly maximum	75	225	112	38
career limit	400	12000	600	200

NOTE: These exposure limits and exposure rate constraints apply to all sources of radiation exposure. In making trade-offs between manmade and natural sources of radiation, adequate allowance must be made for the contingency of unexpected exposure.

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<sup>1</sup>May be allowed for two consecutive quarters followed by six months of restriction from further exposure to maintain yearly limit.

<sup>2</sup>These dose and dose rate limits are applicable only where the possibility of oligospermia and temporary infertility are to be avoided. For most manned space flights, the allowable exposure accumulation to the Germinal Epithelium (3 cm) will be the subject of a risk/gain decision for particular programs, missions, and individuals concerned.

## 7.0 ASTRODYNAMIC CONSTANTS

The values given in Sections 1.6 and 2.7 of NASA TM X-64627 shall be used.

#### REFERENCES

1. Daniels, Glenn E., ed., 1971: Terrestrial environment (climatic) criteria guidelines for use in space vehicle development, 1971 revision. NASA TM X-64587.
2. Smith, R. E., ed., 1971: Space and planetary environment criteria guidelines for use in space vehicle development, 1971 revision. NASA TM X-64627.
3. West, George S., Jr., ed., 1972: Natural Environment Design Requirements for the Sortie Module. NASA TM X-64668.

APPROVAL

NATURAL DESIGN REQUIREMENTS FOR THE SPACE TUG

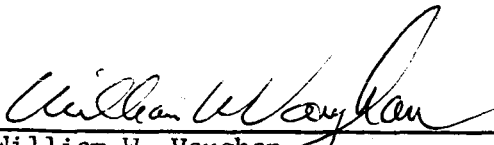
by George S. West

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.



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